Near-Surface Temperature Variation During Total Solar Eclipse, 22 July 2009: A Ground-Based Observational Study at Rangapukur, Raiganj, India

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Abstract

This study investigates the variation of near-surface air temperature during the total solar eclipse of 22 July 2009 using ground-based observations. Measurements were conducted using a manually installed Stevenson screen equipped with a maximum–minimum thermometer and a hygrometer. Temperature data were recorded at five-minute intervals throughout the eclipse period.

The observed data indicate a noticeable decline in surface temperature during the progression of the eclipse, followed by a gradual recovery after totality. However, the temperature variation did not strictly follow the theoretical expectation due to the influence of variable cloud cover. The presence of clouds modified the incoming solar radiation and contributed to deviations from the idealized temperature trend.

The study highlights the combined role of solar radiation reduction and cloud-induced modulation in controlling near-surface temperature dynamics during a total solar eclipse. These findings emphasize the importance of local atmospheric conditions in interpreting eclipse-related meteorological changes. Furthermore, this study serves as a historical record of manual meteorological observation during the longest total solar eclipse of the 21st century, demonstrating the enduring educational value of basic ground-level atmospheric monitoring

Introduction

A solar eclipse is a rare astronomical event during which the Moon passes between the Earth and the Sun, temporarily blocking solar radiation. During a total solar eclipse, a significant reduction in

incoming solar energy occurs, which can influence atmospheric conditions near the Earth's surface (Aplin, 2016; Gray and Harrison, 2012).

One of the most noticeable effects of a solar eclipse is a decrease in near-surface air temperature (Anderson and Keefer, 1975; Founda et al., 2007). In an ideal situation, where the sky is clear and atmospheric conditions remain stable, temperature is expected to decrease gradually as the eclipse progresses and then rise again after totality (Stoev et al., 2005). However, in real conditions, several local factors such as cloud cover, humidity, and wind can modify this expected trend. Among these factors, cloud cover plays an important role. Clouds can both block incoming solar radiation and trap outgoing terrestrial radiation (Aplin and Harrison, 2003; Gray and Harrison, 2012). As a result, the temperature response during an eclipse may differ from the theoretical expectation.

The total solar eclipse of 22 July 2009 provided an opportunity to study such variations under real atmospheric conditions. In this study, near-surface temperature was recorded at short time intervals to examine its trend during the eclipse. Special attention was given to understanding how cloud cover influenced the observed temperature changes. While modern observations increasingly rely on automated digital sensors and satellite data, this documentation serves as a valuable historical record of manual meteorological observation during the longest total solar eclipse of the 21st century. It also emphasizes the educational significance and effectiveness of fundamental ground-level atmospheric monitoring in capturing complex environmental responses.

Study Area and Methodology

The study was conducted at Rangapukur (25°37′12.0″ N, 88°09′36.0″ E), a village located near Raiganj in the state of West Bengal, India. The site was selected after careful consideration of local weather conditions and observational requirements for the total solar eclipse of 22 July 2009.

Prior to the eclipse, several observation groups planned to camp at locations such as Ramganj near Islampur, as this region lay close to the central line of totality and offered a longer duration of total eclipse. However, based on an analysis of long-term rainfall data and the known variability of the

monsoon, it was considered that cloud cover could significantly affect visibility and measurements. Therefore, instead of travelling a long distance, a nearby location was selected where logistical control and instrument safety could be better ensured.

Rangapukur was chosen as the observation site because it provided a relatively open eastern sky, lower public disturbance, and the availability of local support for safeguarding instruments. The observation setup was installed one day prior to the eclipse to ensure stability and protection.

A mini Stevenson screen was installed at a height of approximately 3.5 feet above the ground on a wooden platform. Inside the screen, a Six's maximum–minimum mercury thermometer and a hygrometer were placed to record atmospheric conditions. In addition, a standard alcohol thermometer and a small digital thermometer were used for supplementary observation. The instruments were duly calibrated prior to observation. Temperature observations were taken manually at five-minute intervals throughout the duration of the eclipse. Cloud cover values were estimated visually using quadrant-based sky assessment, which may introduce minor observational uncertainties. Although relative humidity was also measured during the observation period, it could not be retrieved due to data loss.

In addition to meteorological observations, visual and photographic documentation of the eclipse was also carried out using optical instruments, including telescopes and cameras. However, the primary focus of the present study is the variation of near-surface temperature during the eclipse event.

Efforts were also made to engage local people and reduce misconceptions associated with eclipse-related beliefs.

Results and Discussion

The observed variation in surface air temperature during the total solar eclipse of 22 July 2009 shows a distinct but non-uniform pattern (**Table 1; Fig. 1**).

Table 1. Near-surface temperature and cloud cover during TSE 2009

Time (IST)	**Temperature (in ºC)**	**Estimated Cloud Cover (in %)**
05:20	27.0	60
05:25	27.0	75
05:30	27.0	75
05:35	27.0	80
05:40	27.1	75
05:45	27.0	70
05:50	27.1	75
05.55	27.0	75
06:00	27.1	70
06:05	27.1	60
06:10	27.0	75
06:15	27.1	70
06:20	26.9	75
06:25	26.7	60
06.30	26.5	60
06:35	27.1	70
06.40	27.0	75
06:45	27.0	70
06:50	27.3	60
06.55	27.5	50
07:00	27.7	50

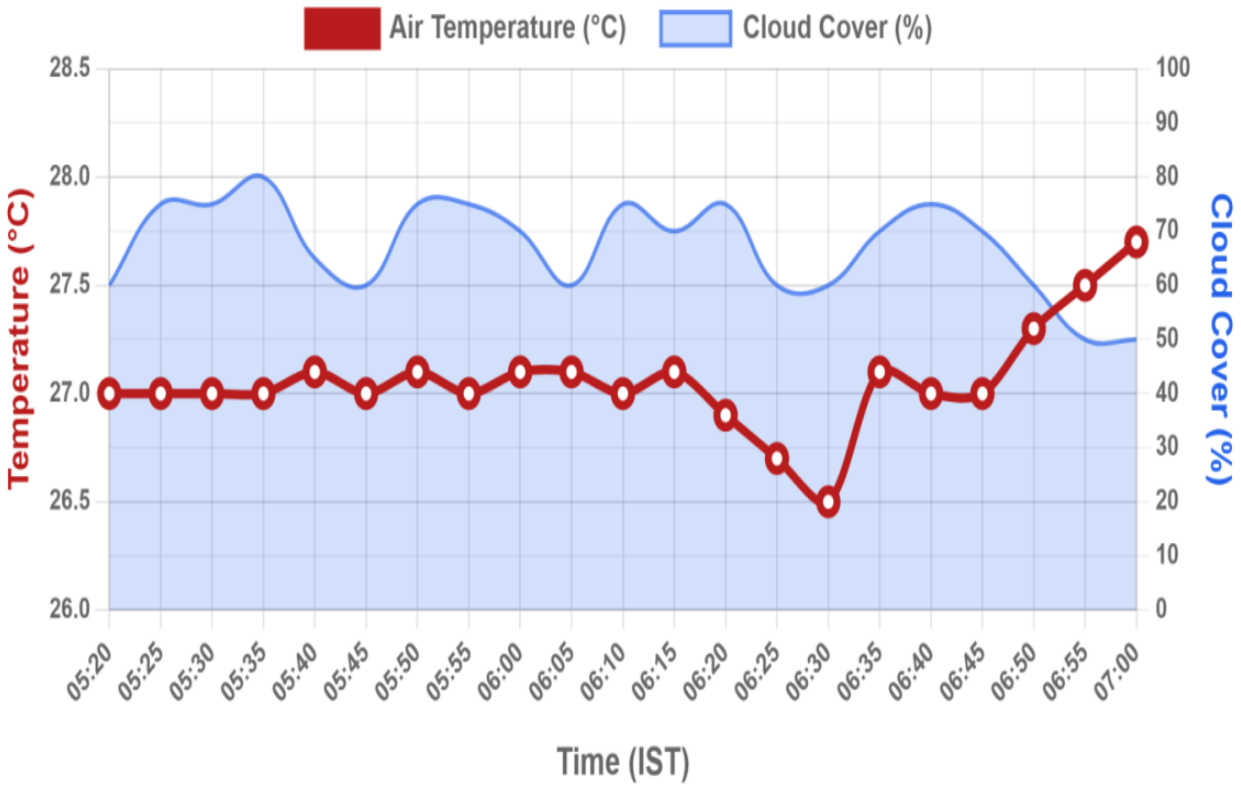

Figure 1: Variation of near-surface air temperature (°C) and cloud cover (%) during the eclipse.

The temperature remained nearly stable at around 27.0°C during the early phase (Figure 2) of observation (05:20–05:50 IST) indicating relatively steady atmospheric conditions prior to the major eclipse influence.

Figure 2: Sky condition before the onset of the eclipse.

A gradual fluctuation is observed between 05:50 and 06:15 IST, where temperature variations remain within a narrow range (±0.1°C). This suggests that, despite the ongoing partial phases of the eclipse (Figure 3), the effect on surface temperature was moderated, likely due to persistent cloud cover and diffused solar radiation.

Figure 3: Early phase of the eclipse showing reduced solar illumination under variable cloud cover.

As the eclipse progressed towards totality (Figure 4), a more pronounced reduction in temperature became evident.

Figure 4: Near-totality phase showing maximum dimming along with significant cloud influence.

During this phase, the solar disk appeared as a narrow crescent, indicating a substantial decrease in incoming solar radiation. The corresponding temperature decline suggests that the surface energy balance was significantly altered as the available solar input diminished.

However, the cooling trend was not perfectly smooth. Short-term fluctuations persisted, likely due to variations in cloud thickness and intermittent transmission of diffused solar radiation. The visual observations show the crescent-shaped Sun under varying cloud conditions, supporting the idea that cloud cover played a key role in modulating the rate of temperature decrease.

The combined effect of reduced direct solar radiation and cloud-induced scattering contributed to a gradual but irregular approach to the minimum temperature observed at totality.

A more pronounced decline in temperature begins around 06:15 IST, reaching a minimum near 06:30 IST (approximately 26.5°C). This phase corresponds to the period of totality (Figure 5). Previous studies have reported temperature drops typically ranging between ~1–3°C depending on local atmospheric conditions. In contrast to ideal theoretical expectations of a smooth and continuous temperature drop, the observed decline is irregular and influenced by short-term fluctuations.

Figure 5: Totality phase capturing the diamond ring effect under partially cloudy conditions.

Immediately after the minimum, a sharp increase in temperature is recorded around 06:35 IST. This rapid recovery suggests a sudden increase in effective solar radiation, possibly due to temporary thinning of cloud cover combined with the post-totality increase in solar exposure (Figure 6).

In the later phase (06:40–07:00 IST), at the end of eclipse, the temperature shows a steady rising trend, eventually exceeding the initial pre-eclipse values. This indicates the combined effect of increasing solar elevation and reduced eclipse influence, along with residual atmospheric heat retention. However, this steady rise is relatively smaller than what is expected under cloud-free condition as still persisting clouds (Figure 7), albeit thin, seems to have moderated the temperature.

Figure 6: Post-totality phase showing gradual recovery of solar illumination.

Figure 7: Final phase showing complete solar disk visibility under persistent cloud conditions.

The photographic evidence (Figures 1–7) clearly indicates significant cloud presence throughout the event. The solar disk is frequently obscured or diffused by varying cloud thickness, resulting in intermittent attenuation of incoming solar radiation. This leads to a non-linear response in temperature variation.

The deviation from a smooth theoretical temperature curve can be attributed to atmospheric factors, particularly cloud cover and associated radiative processes. Previous studies have shown that meteorological responses to solar eclipses can vary significantly depending on cloud conditions (Aplin and Harrison, 2003; Aplin, 2016). Clouds play a dual role: they reduce incoming shortwave radiation (cooling effect) while simultaneously trapping outgoing longwave radiation (warming effect) (Gray and Harrison, 2012). This complex interaction leads to the observed irregular temperature pattern

The observed temperature variation is governed by changes in radiative energy balance at the surface. During the eclipse, the reduction in incoming solar radiation leads to cooling, while the presence of cloud cover modifies this effect by partially trapping outgoing longwave radiation. This combined interaction results in a non-linear temperature response.

Thus, the study demonstrates that local meteorological conditions, especially cloud variability, play a crucial role in modulating the thermal response of the atmosphere during a solar eclipse. Similar observational studies have demonstrated that the temperature response during a solar eclipse may vary depending on local atmospheric factors such as cloud cover (Founda et al., 2007; Stoev et al., 2005). The results emphasize that real-world observations may significantly deviate from simplified theoretical models, highlighting the importance of simultaneous sky condition monitoring in eclipse-related studies.

The present study investigates the variation of near-surface air temperature during the total solar eclipse of 22 July 2009 based on ground-based observations. The results show a clear but non-uniform temperature response throughout the eclipse period.

Conclusion

A noticeable decline in temperature was observed as the eclipse progressed towards totality, followed by a recovery phase after maximum obscuration. However, the temperature variation did not follow a smooth theoretical trend. Instead, it exhibited short-term fluctuations and irregularities.

The analysis indicates that local atmospheric conditions, particularly cloud cover, played a dominant role in modifying the expected temperature pattern. The presence of clouds influenced both incoming solar radiation and outgoing terrestrial radiation, leading to a complex and non-linear thermal response. This study highlights the importance of considering real atmospheric conditions in eclipse-related meteorological observations. It demonstrates that simplified theoretical expectations may not fully represent actual environmental behaviour, especially under variable cloud conditions. Beyond its meteorological findings, this historical dataset underscores the educational significance of manual atmospheric monitoring, proving that fundamental observational techniques can still effectively document rare astronomical events and contribute to citizen science.

Future studies may incorporate simultaneous measurements of additional meteorological parameters such as solar radiation, wind speed, and humidity to better understand the atmospheric response

during solar eclipses. The use of automated data logging systems with higher temporal resolution could further improve the accuracy of observations.

Comparative studies across different locations and varying sky conditions would also help in developing a more comprehensive understanding of eclipse-induced atmospheric changes.

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